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Large scale wind power integration in China: Analysis from a policy perspective

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ABSTRACT

Between 2006 and 2010 the installed capacity of wind power in China has doubled and by 2010 China's cumulative installed capacity of wind power ranked the first in the world, surpassing the United States. However, the rapid expansion of installed capacity has not been matched by grid connection, and this deficiency has aroused the concern of both policy makers and scholars. Unlike most of the current studies which focus on technical strategies in China's wind power industry, this paper analyzes the problem from a policy perspective. The paper analyzes the four challenges that large scale wind power integration in China faces: the uncoordinated development between wind power capacity and power grids; the lack of suitable technical codes for wind power integration; the unclear nature of the grid companies' responsibility for grid connection; and the inadequate economic incentives for grid enterprises. To address these problems, the paper recommends that the government: formulates policies to better coordinate the development of wind power and the planning and construction of power grids; establishes grid codes that reflect in particular the requirements to be met by users of power transmission and distribution networks; and integrates administrative intervention and economic incentive policies to stimulate the grid enterprises' enthusiasm to absorb wind power generation.

Contents

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1. Introduction

Wind power in China has undergone rapid development in recent years. This has been driven by a unique combination of a rapidly growing economy and electricity demand, together with a clear and unambiguous commitment on the part of the government to develop wind power in order to diversify the electricity supply, make the overall economy more energy efficient, create a domestic industry with global leadership potential and at the same time reduce carbon emissions. The installed capacity of wind power has doubled for five years successively between 2006 and 2010. The original goal of 5.0 GW by 2010 was achieved 3 years earlier in 2007. In 2010, China surpassed the United States and ranked the first in terms of cumulative installed capacity of wind power reaching 41.8 GW [1]. This amounted to about 5% of total generation capacity. The reality is evolving so fast that the Chinese government has put forth new objectives for 2020 at 150 GW instead of the original 30 GW.

While the total installed capacity of wind power has expanded greatly, the level of wind power generation remains rather low. According to the statistics released by the China Electricity Council, in 2010 wind power generated 49.4 billion kWh of electricity, accounting for only 1.17% of the nation's total electricity production [2]. The contributory factor for the low ratio of wind power generation is the problems on grid connection of wind power, or, in other words, the absorption of wind power by the electric grids. Thus, one of the core challenges for wind power to contribute more to the energy supply in China is how to effectively integrate significant amounts of wind power into China's electricity systems.

What is more, in 2008 the government formulated planning for seven GW-scale wind power bases and several MW-scale wind power bases. Such wind power bases are mainly concentrated in "three norths" (the northeast, the central north, and the northwest) areas with rich wind energy resources. A significant problem is that many of these bases are generally located in remote areas far away from the power load centers and artery grids. Therefore, such large-scale and concentrated development of wind power generation depends on the construction of high-voltage, long-distance transmission grids. In addition to the large-scale construction of power grids, the structural peak-adjusting capacity inside the electric grids is inadequate, and this has brought about unprecedented technical and management challenges to the safe and stable operation of the electric grids of the local areas and even the whole regions. Therefore guaranteeing large-scaled renewable power generation and grid connection has become an important task for the future large-scale development and utilization of wind power in China.

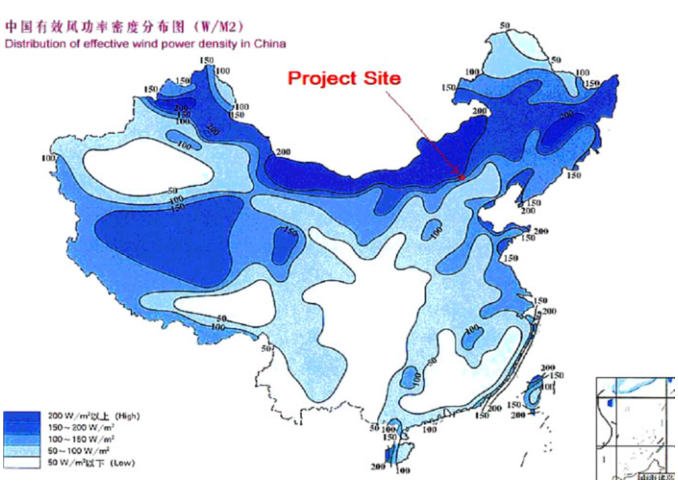


Fig. 1. Distribution of the effective wind power density in China.

A number of Chinese scholars have examined the problems and solutions for large-scale wind power integration in China, but these papers study the issue, by and large, from the perspective of technology strategy [3–5]. However, as pointed out by Jiang Liping, vice president of the State Grid Energy Research Institute, comprehensive strategies including both technology strategies and management strategies are needed for large scale wind power integration in China [6]. Unfortunately, up to now few papers have analyzed the problem from a policy perspective.

This paper aims to analyze policy issues that need to be addressed for large-scale wind power integration in China. The paper is organized as follows: Section 2 reviews wind power development in China in recent years; Section 3 discusses major problems that need to be addressed for large-scale wind power integration in China; Section 4 makes policy recommendations; Section 5 is concluding remarks.

2. Wind power development in China

2.1. Wind resources in China

According to the results of the Third Nationwide Survey of Wind Energy Resources organized by the China Meteorological Administration in 2004–2005, China's vast land areas and long coastlines possess one of the world's largest wind resources. It has a total exploitable wind energy resource of about 4350 GW, of which about 1000 GW onshore and 200 GW offshore can be commercially developed with currently existing technologies. The technically exploitable wind energy resources at a height of 10 m above the ground level could reach 2548 GW, without taking into account the Qinghai-Tibet Plateau [7]. As shown in Fig. 1, about 75% of China's rich onshore wind resources are concentrated in the northwestern grasslands and the Gobi desert, stretching covering an area spanning Henbei, Inner Mongolia, Ningxia, Gansu and Xinjiang.

One of the characteristics of wind energy resources in China is that the geographical distribution of wind energy resources is mismatched with the electrical load.[1] The coastal areas of China have a large electrical load but are poor in wind energy resources. Wind energy resources are plentiful in the north, but the electrical load is small. This poses difficulties for the economic development of wind power. Since most of the regions with abundant wind energy resources are distant from the electrical load centers and the present electricity grid network is weak, the large-scale development of wind power requires substantial extension and strengthening of the electricity grid.

2.2. Installed capacity of wind power

China has been developing its wind resources for over two decades, but had accumulated only about 345 MW of installed capacities by 2000, equivalent to a small coal-fired plant. Between 2000 and 2005, wind power installed capacity in China increased by 20% annually. Since the adoption of the Renewable Energy Law (the Law) in 2006, China has been making rapid strides in harnessing wind resources, doubling its wind power generation capacity each year. Its cumulative installed wind power capacity has increased from 12.72 GW in 2005 to 41.8 GW in 2010. China has supplanted the United States to become the country with the most installed wind power capacity (Fig. 2).

[1] The same problem exists for most coal, oil and natural gas reserves.

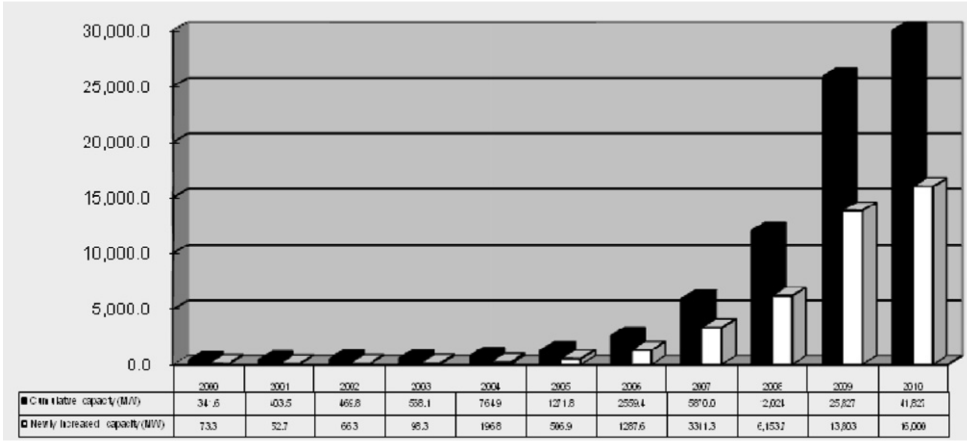


Fig. 2. Wind power installed capacity in China: 2000–2010.

2.3. Wind farm construction

In 1986, China built its first wind farm in Rongcheng, Shandong Province. From 1996 to 1999, in-grid wind power had developed very quickly, entering a localization stage. By the end of 2009, 423 wind farms had been built throughout the country with 20,637 wind turbines installed, totaling 25.83 GW. A total of 24 provinces and autonomous regions (excluding Hong Kong, Macao and Taiwan) had their own wind farms in China. There were over nine provinces with a cumulative installed capacity of more than 1000 MW, including four provinces exceeding 2000 MW [8].

Wind farms in China have a notable characteristic of large scale development. By the end of 2009, each of the 54 wind farms that had been constructed had a capacity of more than 100 MW, totaling 8.11 GW. Most wind turbines ranged from 500 kW to 1 MW, accounting for 84% of China's wind turbine generators. Meanwhile, the installed capacity of wind power in northwest, north and northeast China were 6.27 GW, 6.80 GW and 2.10 GW, respectively, with a total installed capacity of 15.17 GW, accounting for about 87% of the grid-connected capacity in China.

Considering that wind energy resources are mainly concentrated in the northwest, north and northeast, the "three northern areas in China", the Chinese government gradually shifted its concept of wind power development towards the idea of establishing large bases and connecting with a new larger grid. Since 2008, under the leadership of the National Energy Bureau, the planning of 10 GW-scale wind power bases in Gansu, Xinjiang, Hebei, the eastern and western part of Inner Mongolia, Jilin and the coastal area in Jiangsu (see Fig. 3) has been completed to the extent of an assessment of the wind energy resources and preparation for construction. According to the plan, all these wind power bases will contain a total installed capacity of 138 GW by 2020, and on the assumption that a supporting grid network is established [8].

2.4. Wind equipment industry

The rapid capacity expansion and incentive policies, such as the 70% localization requirement[2] introduced by the Chinese government, have stimulated the domestic wind equipment industry, which is expanding quickly to meet the high demand for wind turbines. By the end of 2009, there were 80 domestic manufacturers (including joint ventures) of wind turbines of different sizes [8], and more companies would like to enter the market. Consequently, they were gradually enlarging their combined share in China's turbine market, rising to a total of 88% in 2009 from less than 10% in 2000. In 2008, the share of domestic manufacturers and joint ventures in China's turbine market was 61.6%. The Xinjiang Gold Wind Inc., located in Xinjiang, had the biggest market share, accounting for 21.6%. Foreign manufacturers shared the remaining 38.4% of turbine market, among which Gamesa of Spain took the biggest shares, accounting for 12.8% of the total cumulative installed capacity.

Following the planning of the national GW-scale wind power bases, domestic manufacturers of complete turbines have accelerated their industrial expansion for two years in succession. The complete turbine manufacturers, including Goldwind, Sinovel Wind Power, Guodian United Power and Guangdong Mingyang, have all established manufacturing plants close to the wind power bases. Because they are close to the point of installation, this decision effectively minimizes transportation costs and ensures the timing of deliveries, which in turn has a positive influence on the development of the enterprise.

Some local governments have introduced policies to encourage the machine manufacturers to build plants in order to speed up the development of a local manufacturing industry and increase their tax revenue. Such administrative intervention, however, is bound to result in scattered distribution of manufacturing bases, which has caused considerable concern.

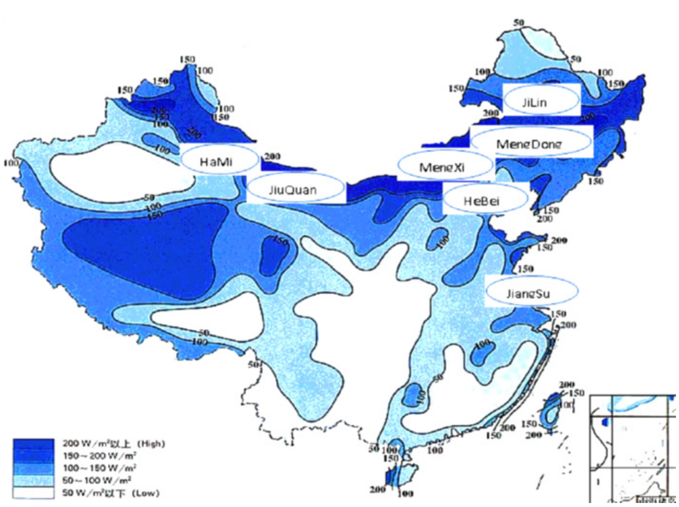


Fig. 3. Distribution of seven 10 GW-scale wind power bases in China.

[2] This policy had been implemented since 2003 and was revoked in 2009.

3. Major challenges for large scale wind power integration in China

Despite the rapid expansion of installed wind power capacity, the development of wind power in China is increasingly restricted by the capacity of the local grids and transmission lines. Of the 5.9 GW of total installed capacity at the end of 2007, only 4 GW was connected to the grid. In January 2008 alone, some 300 GWh of electricity was wasted due to insufficient transmission capacity. According to data released by the China Power Union in 2009, only 72% (8.94 GW) of China's total wind power capacity was connected to the grid. As a result, a large number of wind turbines have been "sun bathing"—as the Chinese call it—and less than 1% of total electricity production comes from wind power. In the first quarter of 2010, the amount of wind power that was not utilized because of not being connected to the grid reached almost 0.3 TWh, which is a significant amount of generation, given that the total wind power generation only reached 0.5 TWh in the same period [9]. The State Electricity Regulatory Commission in its report released in 2009 said that many wind farms across China were in difficult operation positions, some wind farms even suffered financial losses and one-third of wind turbines were idle [10].

The "bottlenecks" preventing the dispatch of wind power onto the transmission network are due to: (1) uncoordinated development between wind power and power grids; (2) lack of suitable national technical codes for wind power integration; (3) unclearly defined responsibility for gird connection of the part of the grid enterprises; and (4) insufficient economic incentives for grid enterprises. The following analysis on these factors is to be made mainly from a policy perspective.

3.1. Uncoordinated development between wind power and power grids

The main contributory reason for the uncoordinated development between wind power and power grids is that the current policy system gives little consideration to grid connection policy for wind power. In recent years, China has emphasized more on the wind equipment manufacturing industry and market development. The powerful policy supports for the manufacturing industry include the subsidy offered to wind power generating enterprises with independent intellectual property rights, and the requirement that franchised wind power generating projects shall guarantee equipment localization rate of 70%, on-grid power price policy and tax preferential policy. But less attention has been paid to the transmission and accommodation of wind power.

The consequence is that the planning for wind power development focuses on the planning for wind power resources rather than on the construction of wind power generation capacity, and thus results in serious problems of wind power absorption, especially in areas with rich wind resources. For example, by the end of 2009, the installed capacity of Mengxi (or West Inner Mongolia) reached 4.23 million kW, among which 1 million kW was not transmitted due to grid constraint.[3]

3.2. Lack of suitable state technical codes for wind power integration

Wind turbines have been treated as embedded generators, and they were not expected to contribute to the control of power system voltage or frequency. In addition, wind farms were required to disconnect from the grid under abnormal operating conditions. At the early stage of development, wind farms connected to the grid in China were small-sized installations, connected at distribution voltage levels and the total amount of wind power capacity installed was small in proportion to the total amount of installed generation capacity. As a result, there was previously little need for such installations to meet a defined set of grid connection technical performance requirements. However, as the amount of wind power connected to the grid increases, this situation has started to change. The penetration of wind power has reached levels high enough to affect the quality and stability of the grid.

In 2005, the *Technical Rules for Connecting Wind Farms to Power System (GB/Z19963-2005)* drafted by the State Grid, a state-owned grid company, took effect. However, the rules were not effectively implemented since they are only rules made by a utility and are not legally compulsory. To date, there are no suitable national technical standards for grid connection of wind power, which leads to lack of power for driving the wind power equipment manufacturers to develop and manufacture wind turbines that meet the requirements of the electric grids. In addition, the lack of provision relating to the prediction of power output from wind farms leads to the situation that the electric grid enterprises have no right to require the wind farm to such predictions.

3.3. Unclear definition of grid enterprises' responsibility for grid connection

The Law requires the grid companies to provide grid connection to and to off-take all the power generated by certain types of renewable energy technologies. It also guarantees minimum prices or subsidies. For wind power projects approved by the National Development and Reform Commission (NDRC), the Law requires the grid enterprises be responsible for constructing transmission lines on time to connect the wind farms to the nearest grid as well as to purchase all the electricity generated by the wind farms [11].

Generally speaking, these provisions on wind power grid connection have imposed social responsibilities and pressures on the grid enterprises and have caused them to make efforts to absorb wind power. Priority to grid connection of wind power generation has been basically guaranteed, and the compulsory on-grid system has been implemented effectively since 2006.

However, the provisions have two obvious deficiencies with regard to responsibilities and means of implementation: firstly, the almost unconditional requirement "to purchase all power" is emphasized; secondly, the penalty to be imposed on the grid utility if it fails or refuses to absorb wind power is not specified. In other words, whether to absorb wind power and how much wind power to be absorbed largely depend on the sense of responsibility of the grid enterprises. Thus, the grid enterprises are often reluctant to accept the connection of wind farms into their transmission and distribution networks.

3.4. Insufficient economic incentives for grid enterprises

For wind power projects approved by the NDRC, the Law also requires (1) that the tariff for uploading electricity to the power grid be determined through a nationwide concession bidding process, taking into consideration the power generation costs, loan repayments and a reasonable profit; (2) that the gap between the wind electricity tariff and the average electricity tariff be shared across the whole power grid, through collecting a levy on each kilowatt-hour of electricity sold to the end users.

As laid down in the Law and the implementation details of cost-sharing by the NDRC, compensations for grid companies which purchase wind power are as follows: a subsidy of 0.01 yuan/kWh

[3] The result was obtained from a survey conducted by the team of project "Research on the regulation measures for expanding generation of grid-connected wind power: take Northeast China as an example" funded by the Energy Foundation USA in 2010. The author Sufang Zhang is a member of the project team.

of electricity integration for wind farms which are less than 50 km away from the main grid infrastructure; a subsidy of 0.02 yuan/kWh for 50–100 km and 0.03 yuan/kWh for more than 100 km [12,13]. However, compared with the overall revenue of the power grid enterprises, this income is minimal and not enough to encourage enterprises to actively accept wind power.

The basic problem with the policy is that it fails to take full consideration of cost to the power system of integrating wind power, including the potential effects of efficiency reduction and interest loss caused by the participation of peaking power stations, backup power and the cost of long-distance transmission of wind power through the grid and related power investments. The frequent start-up of peaking units, for example, reduces power generation efficiency or forces the company to sacrifice other easily controlled electricity production options for wind power, thus reducing their own income. No mechanism exists to compensate the power companies for this particular dilemma.

4. Policy recommendations

In order to promote large scale wind power integration, ensure the stability and sustainability of the development of wind power industry and obtain best development at lowest cost in China, the following policies are recommended:

4.1. Better coordinate the development of wind power and the planning and construction of power grids

China needs to significantly improve its power grids and to better coordinate the development of wind power and the planning and construction of power grids. New transmission lines will have to be constructed simultaneously as more wind power farms are built. Moreover, given the significantly growth of wind power capacity planned for 2020, China should now place more pressures on the grid companies to ensure the actual flow of power to the grid rather than just meeting capacity. Special policies for optimizing power grid construction should be formulated, aiming at establishing a mechanism to encourage and guide the power grid enterprises to absorb wind power.

It is also recommended to include wind power development in the overall planning of the nation's grid construction and to work out future development plans for wind power suppliers, other power suppliers and the grid as early as possible on a national scale, including increasing the grid capacity of the main wind power concentration regions. This would include focusing on the layout and construction of power supply, taking into account adjustment capacity such as pumped storage, and encouraging the production and application of thermal power equipment with wide adjustment capability. At the same time, efforts should be continued to enhance connections between regional grids and to improve the overall regulation of the national grids.

4.2. Establish grid codes to enhance the wind farm capability to fulfill the safe and stable operation requirement of grid

High penetration of wind power challenges wind turbine operators to supply reliable power and extract optimum power from the wind. Strengthening wind power forecasting and improving the performance of individual wind turbines can enhance wind power's ability to meet the requirements of grid compatibility. Hence, technical codes which reflect in particular the requirements to be met by users of power transmission and distribution networks become essential.

The process of establishing grid codes involves the interests of four main interest groups: wind farm developers, wind turbine manufactures, existing system users and utilities. On one side, wind farm developers and manufacturers are likely to be reluctant to accept new requirements that may increase the cost of the wind farms but at the same time should be interested in having a clear set of requirements which will allow standardizing production. On the other side, existing system users and utilities are concerned on the safety and effective management of the system. Wind farm developers and network operators must work together to define a set of minimum technical performance requirements in order to accommodate significantly greater volumes of wind generation without destabilization of the grid and to ensure continuing maintenance of network security and hence security of supply while allowing a greater volume of wind farms to be connected to the system [14]. The main requirements of typical technical codes include voltage fluctuation range, continuous voltage operating range, reactive power capability and fault ride through (FRT).

China needs to follow the lead of other countries with a large quantity of wind power such as Denmark, Germany and Britain which have implemented technical codes for the integration of wind power into the electricity grid system. Technical codes for wind power integration vary from one country to another as each has different power system control needs. However, all requirements for wind power have to be consistent with the regulatory requirements for conventional sources of power and should ensure the safe and reliable operation of the energy system.

At present, domestic wind turbines in China break down more often and have overall capacity factors of several percentage points lower than foreign models. Thus, it is crucial to improve the quality of the increasingly used, domestically made turbines.

4.3. Improve administrative intervention and economic incentive policies

Chinese grid enterprises lie between wind power generators and end consumers in the wind power supply chain and hold a monopoly position at both the purchasing and selling ends of the chain. Such monopoly power should be regulated by the government in order to maximize social welfare. For example, grid enterprises should be required to ensure a proportion of grid construction investment for accommodating wind power and to carry out grid construction planning to match the approved wind power projects. Lack of quotas defined for power grid enterprises has been one of the main reasons for the failure to implement the guaranteed acquisition system for wind power. In order to promote the reform and development of grid, a quota system should be designed in order to set a quantity or proportion of wind or other renewable energy which should be purchased by the gird enterprises. Through the implementation of such a quota system, power grid enterprises would be required to purchase a certain quota of wind power and their responsibility would be clearly defined. Meanwhile, operative penalty policies should be stipulated to ensure the implementation of the quota system.

In addition to administrative intervention, economic incentives for grid enterprises should be improved. The subsidy level for grid connection expenses should be raised. The grid connection expense refers to the investment on power transmission, transformation, operational and maintenance expenses incurred by the grid enterprises for wind power generating projects. As previously noted, the subsidy standards for grid-connection expenses according to the route length are generally deemed to be slightly low inside the industry. The practical reason for this is that the current compensation standards have only considered the recovery of the electric grid and route investment for grid connection of wind power generating projects, or, in other words, compensation for the investment needed to connect the wind farm into the current grid connecting system of the artery electrical grid. However, recovery of the investment in new ultrahigh voltage and extra-high voltage networks and

compensation for peak adjustment in other power generating units have not been taken into consideration. Therefore, it is necessary to improve the compensation standards.

5. Concluding remarks

At present, on the one hand, the wind power generation industry in China has expanded rapidly, and policies have been put in place relating to power price, investment and taxation. On the other hand, China still lies in the initial phase of wind power development, and the grid enterprises have limited experience in absorbing wind power. Thus wind power transmission and market absorption should be the main emphasis in policy support. Policies need to direct wind power development from the perspective of promoting the national scaled development of grid connection of wind power.

Firstly, the state should strengthen the management of the construction of wind power projects and should incorporate construction of wind power into construction and planning of the electric grids; secondly, technical codes which reflect in particular the requirements to be met by users of power transmission and distribution networks should be established; and, thirdly, policies for administrative intervention and economic incentives should be integrated to stimulate the grid enterprises' enthusiasm to absorb wind power generation.

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